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**TEMPERATURE AND PRECIPITATION VERIFICATION RESULTS
AND INTERPRETATION AT WFO CORPUS CHRISTI AND OTHER
WFOS JANUARY 2004 THROUGH JUNE 2006**

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I. Introduction

The National Weather Service (NWS) maintains a long-term record of public forecast verification statistics for the following elements: maximum and minimum temperature and 12-hour Probability of Precipitation (PoP) (NWS Directive 10-1601, 2005). Quality controlled data are archived in a central database and are available to NWS employees through query, using the Stats on Demand feature of the NWS Verification Web page: (<https://verification.nws.noaa.gov/>). A list of verification sites, known as the legacy network, appears on this Web site, and data are available for most of these locations from April 1966 to September 2004. Prior to 2004, NWS temperature and PoP forecasts were formulated and transmitted using the Coded Cities Forecast (CCF) product. Initially, the CCF provided maximum and minimum temperature forecasts for the first five periods¹, and PoP forecasts for the first three periods² for these legacy sites. In January 2004, verification using the Point Forecast Matrices (PFM) product began. In the PFM, maximum and minimum temperature and PoP forecasts are provided for 14 periods (7 days) for several locations (including the legacy sites) within a Weather and Forecast Office's (WFO) area of responsibility. On the NWS Verification Web page, WFO forecasts can be compared with model guidance for the same periods. The rationale for model vs. WFO comparisons include identifying model and WFO biases and errors and the degree to which WFO forecasters add value to the model guidance at each verification site.

WFO Corpus Christi, Texas, has a robust verification program, providing timely monthly and seasonal station and individual forecaster statistics to the operational staff using various on-station verification programs. These programs provide temperature and precipitation verification statistics, comparing WFO Corpus Christi forecasts with Model Output Statistics (MOS) from three sources: GFS-MOS forecasts (generated from the Global Forecast System), the MET-MOS (generated from the North American Mesoscale³ model) and the FWC-MOS (generated from the NGM, or Nested Grid Model).

In this paper I will discuss and illustrate the statistical comparisons between temperature and precipitation forecasts provided by WFO Corpus Christi with those provided by the various MOS forecasts from 1 January 2004 through 30 June 2006. This 30 month period of record was chosen, since national verification statistics using the Point Forecast Matrix product began in January 2004, and because June 2006 was the latest data available during the initiation of this study. I will also show how GFS-MOS and WFO Corpus Christi verification statistics compare with other WFOs in the NWS Southern Region and across the United States. Because of the consistently impressive verification results at WFO Corpus Christi when compared with other WFOs, this paper will also discuss possible reasons why WFO Corpus Christi has been able to remain at or near the top nationally in adding value to the GFS-MOS guidance.

¹ A period for a temperature forecast is defined as follows. The period for maximum temperature verification occurs between 7 AM and 7 PM Local Standard Time (LST), while the period for minimum temperature verification occurs between 7 PM and 8 AM LST.

² A period for a precipitation forecast is a 12-hour interval either between 6 AM and 6 PM LST (daytime) or 6 PM and 6 AM LST (nighttime).

³ The current NAM model version is NAM/WRF, which utilizes the non-hydrostatic Weather Research and Forecasting (WRF) model, and is separate from the NAM/ETA model from which the MET-MOS values are obtained.

II. Brief History of the Corpus Christi Verification Program

The local temperature verification program began at WFO Corpus Christi in 1998, with Corpus Christi (KCRP), Victoria (KVCT), and Laredo (KLRD) as the legacy verification sites in the WFO Corpus Christi Coded Cities Forecast product (CCFCRP). Temperature verification statistics such as CCF and MOS errors, biases, CCF percent improvement over MOS, and the percentage of CCF forecasts 3°F or less from observed were provided to the forecasters on a monthly basis for the first five periods using the SOOVER program (Frederick, 1999). Monthly precipitation statistics, including CCF and MOS Brier Scores (BS), average POP for measurable rainfall, trace rainfall, and no rainfall also were provided to the staff, using a locally written program. Eventually, warm season (April through September) and cool season (October through March) temperature and precipitation verification statistics were also presented for the first five periods, as well as temperature and precipitation verification statistics for each forecaster. A local temperature and precipitation forecast contest also was initiated. In April 2004, three new verification sites were added to the local verification program: Alice (KALI), Rockport (KRKP), and Cotulla (KCOT). Long-term verification statistics (periods 6 through 14) for WFO Corpus Christi and GFS-MOS temperatures began in early 2005. Finally, in October 2005, Kingsville (KNQI) was added as a verification point (Naval Air Station Corpus Christi, KNGP was added in October 2006, after the initiation of this study). Further elaboration concerning the local WFO Corpus Christi verification program is discussed in greater detail in Wilk (2005).

Prior to 2004, national verification of temperatures and precipitation used the CCF from the respective forecast offices. In January 2004, verification using the Point Forecast Matrices (PFM) product began (NWS Directive 10-1601, 2005). In the PFM at WFO Corpus Christi (PFMCRP), point forecasts for 23 cities are provided, including the aforementioned locations in the CCF. Since CCF maximum and minimum temperatures and 12-hour POP forecasts are identical to the forecasts provided in the PFM for these seven sites, CCF verification statistics are identical to the PFM numbers at these locations⁴.

III. Basic Verification Statistics Employed

Verification statistics for WFO Corpus Christi were computed for the CCF, GFS-MOS, MET-MOS and FWC-MOS forecasts for the first five periods. Average absolute temperature errors ($|\text{Error}|$) for the CCF and each MOS forecast were computed by taking the average absolute value difference between forecast and observed temperatures regardless of sign:

$$|\text{Error}| = (1/N) \sum | (f_i - o_i) | \quad (1)$$

where \sum is the summation from i equals 1 to i equals N , o_i is the observed temperature for the i th forecast, f_i is the forecast temperature for the i th forecast, and N is the number of forecasts

⁴ By 1 January 2004, the CCF forecast was extended to 14 periods for both temperatures and precipitation. Therefore, CCF and PFM forecasts are identical for these forecast elements.

for that period. Percent improvement of CCF temperature forecasts (%T_IMP_{CCF}) over each MOS method was computed by:

$$(\%T_IMP_{CCF}) = \frac{ERR_{MOS} - ERR_{CCF}}{ERR_{MOS}} \times 100 \quad (2)$$

where ERR_{MOS} is the absolute error for a particular MOS method, and ERR_{CCF} is the absolute error for the CCF, both computed from equation (1). A positive T_IMP_{CCF} value indicates improvement over MOS, with the opposite true for negative values.

For precipitation, Brier Scores (BS) were computed. The BS is the mean square error of all POP forecasts. The standard National Weather Service (NWS) BS, defined below, is one-half the original score defined by Brier (1950):

$$BS = (1/N) \sum (f_i - o_i)^2 \quad (3)$$

Here, f_i = forecast POP, o_i = observed precipitation occurrence (0 or 1) for a precipitation threshold (usually set at 0.01 inches, i.e., measurable rainfall), and N is the number of forecasts. Ideally, Brier Scores close to zero are desired. CCF percent improvements (%IMP_{CCF}) over each MOS method were then computed:

$$\%IMP_{CCF} = (BS_{MOS} - BS_{CCF}) / BS_{MOS} \times 100 \quad (4)$$

A positive %IMP_{CCF} value indicates improvement over MOS, with the opposite true for negative values. For local verification, statistics were computed for the period 1 January 2004 through 30 June 2006 for the first five forecast periods for all seven sites, using the SOOVER program for temperature verification and a locally written program for precipitation verification. This time interval was chosen since it provided the largest data set available when this study was initiated since national verification statistics began using the PFM. The five (or four) periods of each CCF and MOS statistic were then averaged for each station. Results are shown in the next two sections.

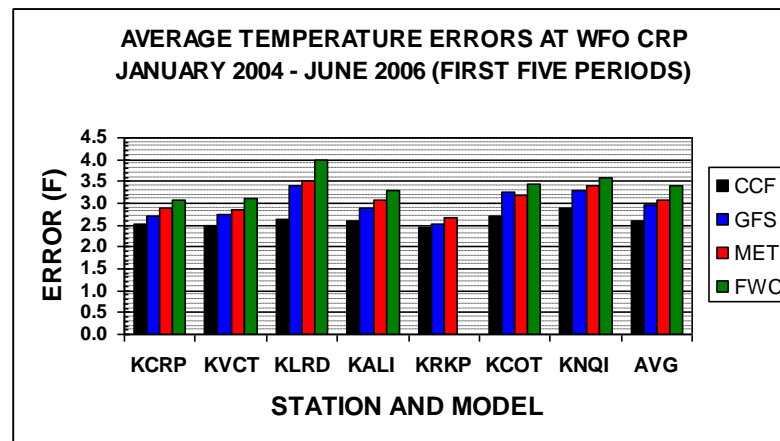
For WFO verification statistics from other offices, data was obtained from the NWS Verification / Storm Data web site (see <https://verification.nws.noaa.gov/> for more details and statistics). It should be noted that the number of verification sites per WFO varies; some WFOs have several verification points, while others may only have a couple sites (see <https://verification.nws.noaa.gov/ICAOWebInterface/PublicList.aspx> for the national PFM verification sites). WFO and GFS-MOS verification statistics were obtained for the 30 month period for the first five periods and all 14 periods for all NWS offices from the web site. SR and national WFO percentage improvements over the GFS-MOS in temperature and precipitation forecasts are presented below⁵.

⁵ For comparisons between WFO Corpus Christi and other WFOs, WFO Corpus Christi verification results are taken from the NWS verification web site.

IV. Temperature Verification Results

Figures 1 and 2 show the average temperature errors (maximum and minimum) and CCF improvement over each MOS method at WFO Corpus Christi for all seven stations, respectively, using the SOOVER program. Clearly, CCF forecasts improved each MOS forecast at all seven sites, with the greatest improvement over FWC-MOS forecasts (possibly due to the poorer resolution within the NGM). Overall, CCF forecasts improved GFS-MOS forecasts by about 11.5%, MET-MOS forecasts by 15%, and FWC-MOS forecasts by around 22%. The greatest improvements over MOS occurred over the inland counties west of KCRP, namely at KALI, KLRD, and KCOT. Overall, CCF improvements over MOS were found to be greater for maximum temperatures than for minimum temperatures (figures not shown).

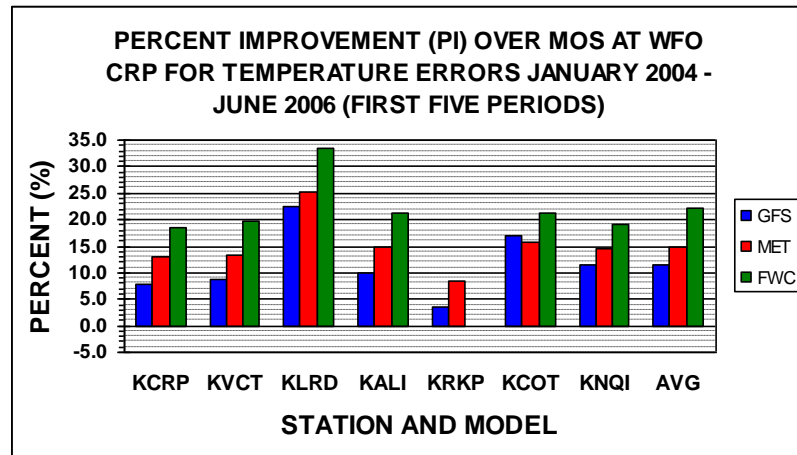
In order to compare WFO Corpus Christi temperature verification results with other offices for the first five periods, temperature verification data was compiled for all SR offices for the same 30 month period. All region and NWS statistics listed below can be obtained at <https://verification.nws.noaa.gov/>. Figure 3 indicates the percent improvement over the GFS-MOS for all WFO verification sites in SR for the period January 2004 through June 2006⁶. As the figure and corresponding table indicate, WFO Corpus Christi had the greatest improvement over the GFS-MOS in temperature forecasts in SR. Also, most offices in region (21 of the 32) showed some improvement over the GFS forecasts. In fact, WFO Corpus Christi showed the greatest improvement



Station	CCF	GFS	MET	FWC
KCRP	2.51	2.72	2.89	3.08
KVCT	2.49	2.73	2.87	3.10
KLRD	2.64	3.40	3.53	3.97
KALI	2.61	2.90	3.06	3.31
KRKP	2.45	2.54	2.68	N/A
KCOT	2.70	3.25	3.20	3.43
KNQI	2.90	3.28	3.39	3.58
AVG	2.61	2.97	3.09	3.41

⁶ The data for SJU may be questionable. When SJU was removed, the average percent improvement for SR increase to 1.8 percent.

Figure 1: Average CCF and MOS temperature errors for all seven verification sites, as well as the average error for all sites. Note that average CCF errors were lower than the average GFS-MOS, MET-MOS, and FWC-MOS at all sites.



Station	GFS	MET	FWC
KCRP	7.7	13.2	18.5
KVCT	8.8	13.2	19.7
KLRD	22.4	25.2	33.5
KALI	10.0	14.7	21.2
KRKP	3.5	8.6	N/A
KCOT	16.9	15.6	21.3
KNQI	11.6	14.5	19.0
AVG	11.6	15.0	22.2

Figure 2: Average CCF improvement in temperature forecasts over MOS (in percent) for all seven verification sites, as well as the average percent improvement for all sites combined. For the FWC-MOS and CCF comparisons, only the first four periods were used.

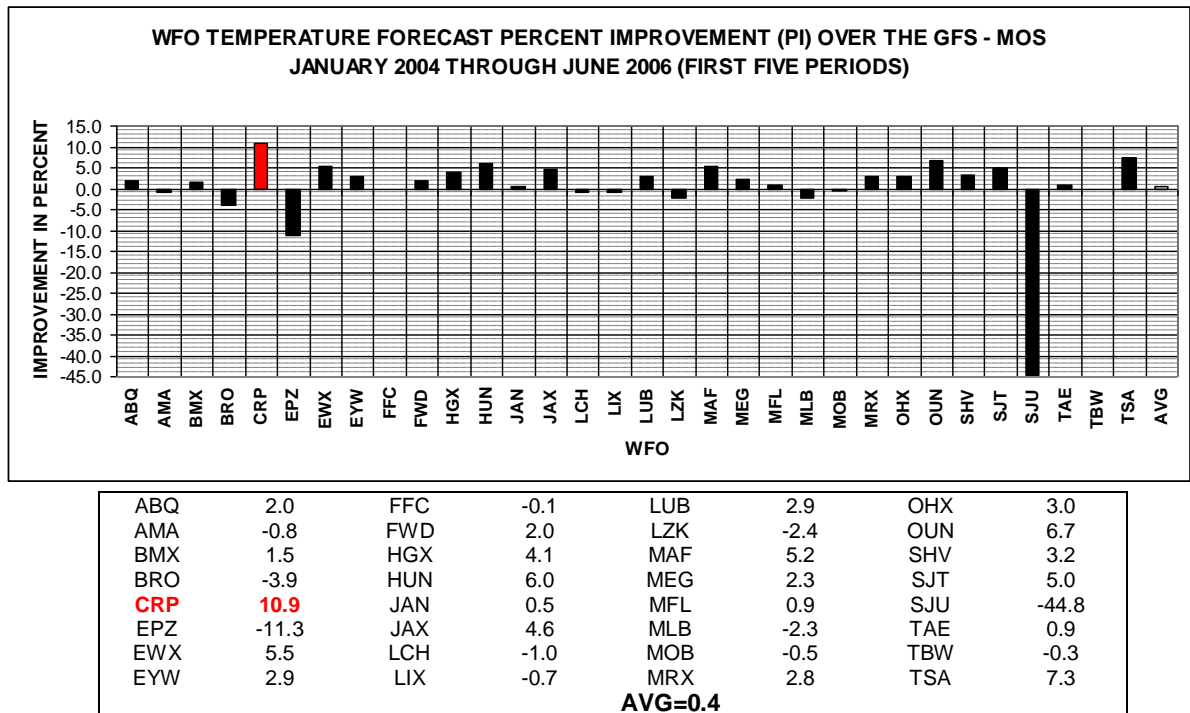


Figure 3: WFO Temperature Forecast percent improvement Over GFS-MOS for all SR Offices for the first five periods. WFO Corpus Christi is in red, with the combined SR average in gray.

over GFS-MOS forecasts for the entire nation, not only for the first five periods, but for all 14 periods (see Tables 1 and 2).

To further investigate improvements over the GFS-MOS for the first five periods, forecasts were separated for times when the WFO and GFS-MOS forecasts were different by 4°F or more, and when the 24 hour observed temperature change was 10°F or greater (Figures 4 and 5, respectively). As these two graphs indicate, WFO Corpus Christi still provided the best improvement over the GFS-MOS in the region for both categories⁷. Unfortunately, in both cases, the region's average improvement over the GFS-MOS was slightly negative. However, for instances when guidance (GUI) and the local forecast (LCL) differed by 4°F or more, 18 of the 32 stations provided improvement over guidance. Thus, most stations in the region provided improvement over the GFS-MOS for the first five periods, even in cases when guidance was suspected to have a large error by the appropriate WFO. For cases when the 24 hour observed temperature change was 10°F or greater, station improvement over the GFS was smaller, with only 10 of the 32 WFOs providing better temperature forecasts than guidance.

**WFO Temperature Forecast Percent Improvement Over The GFS MOS
January 2004 Through June 2006 (First Five Periods)**

WFO	%	WFO	%	WFO	%	WFO	%	WFO	%	WFO	%	WFO	%
ABQ	2	BTX	0.2	EPZ	-11.3	HFO	-13.9	LOT	1.1	MTR	-5.7	RLX	2.4
ABR	1.4	BUF	-0.6	EWX	5.5	HGX	4.1	LOX	1.0	OAX	5.5	RNK	-7.6
AFC	-8.1	BYZ	-1.9	EYW	2.9	HNX	-0.9	LSX	5.0	OHX	3.0	SEW	-3.0
AFG	1.2	CAE	-1.2	FFC	-0.1	HUN	6.0	LUB	2.9	OKX	-0.6	SGF	2.5
AJK	-8.4	CAR	-2.4	FGF	-5.0	ICT	8.1	LWX	-8.1	OTX	-2.4	SGX	-5.6
AKQ	0.8	CHS	0.5	FGZ	-5.3	ILM	0.2	LZK	-2.4	OUN	6.7	SHV	3.2
ALY	0.7	CLE	-2.7	FSD	7.0	ILN	2.0	MAF	5.2	PAH	3.3	SJT	5.0
AMA	-0.8	CRP	10.9	FWA	N/A	ILX	4.6	MEG	2.3	PBZ	-3.8	SJU	-44.8
APX	-3.5	CTP	-1.2	FWD	2.0	IND	0.3	MFR	-6.3	PDT	0.3	SLC	5.2
ARX	0.6	CYS	-0.6	GGW	0.5	IWX	-1.0	MFL	0.9	PGU	N/A	STO	-5.3
BGM	-0.5	DDC	6.6	GID	7.4	JAN	0.5	MHX	-6.9	PHI	-3.7	TAE	0.9
										percent			
BIS	-3.4	DLH	-7.5	GJT	-10.1	JAX	4.6	MKX	1.1	improvementH	-3.8	TBW	-0.3
BMX	1.5	DMX	6.6	GLD	6.7	JKL	3.8	MLB	-2.3	PQR	-4.4	TFX	5.0
BOI	0.7	DTX	-2.5	GRB	2.1	LBF	1.7	MOB	-0.5	PSR	4.4	TOP	8.0
BOU	-6.8	DVN	8.8	GRR	-0.4	LCH	-1.0	MPX	1.7	PUB	-5.9	TSA	7.3
BOX	0.6	EAX	3.5	GSP	3.9	LIX	-0.7	MQT	-3.4	RAH	1.0	TWC	-12.4
BRO	-3.9	EKA	3.8	GYX	-0.6	LKN	-2.3	MRX	2.8	REV	5.6	UNR	-1.7
						LMK	0.2	MSO	2.4	RIW	-6.7	VEF	1.7

⁷ Results using all 14 periods showed that WFO Corpus Christi was 2nd in SR when WFO and the GFS differed by 4F or more (OUN was 1st), and 3rd in region when the 24 hour observed temperature change was 10°F or greater (OUN was 1st and TSA was 2nd).

Table 1: WFO percent improvement over the GFS-MOS for the first five periods at all Weather Forecast Offices in the United States. WFO Corpus Christi showed the greatest improvement over MOS nationally.

**WFO Temperature Forecast Percent Improvement Over The GGS MOS
January 2004 Through June 2006 (All 14 Periods)**

WFO	%	WFO	%	WFO	%	WFO	%	WFO	%	WFO	%	WFO	%
ABQ	-1.8	BTX	-3.0	EPZ	-9.0	HFO	-13.0	LOT	-0.1	MTR	-7.0	RLX	-1.2
ABR	1.0	BUF	-3.2	EWX	2.2	HGX	2.0	LOX	-4.4	OAX	2.0	RNK	-7.0
AFC	-7.3	BYZ	-4.1	EYW	-2.2	HNX	-3.8	LSX	1.2	OHX	-0.2	SEW	-4.3
AFG	-3.8	CAE	-5.1	FFC	-5.2	HUN	2.5	LUB	-0.4	OKX	-2.0	SGF	0.8
AJK	-8.1	CAR	-5.3	FGF	-8.7	ICT	4.4	LWX	-4.4	OTX	-4.3	SGX	-6.4
AKQ	-1.8	CHS	-2.8	FGZ	3.8	ILM	-1.3	LZK	-0.9	OUN	4.0	SHV	0.2
ALY	-1.4	CLE	-3.0	FSD	N/A	ILN	-1.1	MAF	0.2	PAH	0.2	SJT	1.5
AMA	-1.2	CRP	4.5	FWA	0.6	ILX	2.2	MEG	-0.5	PBZ	-3.5	SJU	-40.9
APX	-4.4	CTP	-2.6	FWD	-2.5	IND	-1.0	MFR	-7.1	PDT	-1.4	SLC	0.7
ARX	-1.2	CYS	-2.2	GGW	2.9	IWX	-0.9	MFL	-4.1	PGU	N/A	STO	-7.6
BGM	-2.4	DDC	4.1	GID	-8.7	JAN	-0.1	MHX	-4.9	PHI	-3.2	TAE	-3.0
BIS	-2.6	DLH	-5.0	GJT	1.3	JAX	-0.8	MKX	-1.7	PIH	-5.0	TBW	-2.8
BMX	1.3	DMX	2.2	GLD	1.4	JKL	-1.6	MLB	-3.4	PQR	-5.5	TFX	-0.9
BOI	-3.3	DTX	-2.5	GRB	0.5	LBF	-0.6	MOB	-2.9	PSR	-2.4	TOP	2.3
BOU	-7.7	DVN	4.3	GRR	-0.5	LCH	0.1	MPX	0.1	PUB	-6.2	TSA	3.1
BOX	-1.7	EAX	-0.1	GSP	-4.6	LIX	-1.1	MQT	-2.8	RAH	-0.3	TWC	-12.0
BRO	-5.5	EKA	-10.2	GYX	-9.0	LKN	-4.2	MRX	-0.7	REV	2.9	UNR	-3.3
						LMK	-2.5	MSO	-0.6	RIW	-8.3	VEF	-1.6

Table 2: Same as Table 1, except for all 14 periods.

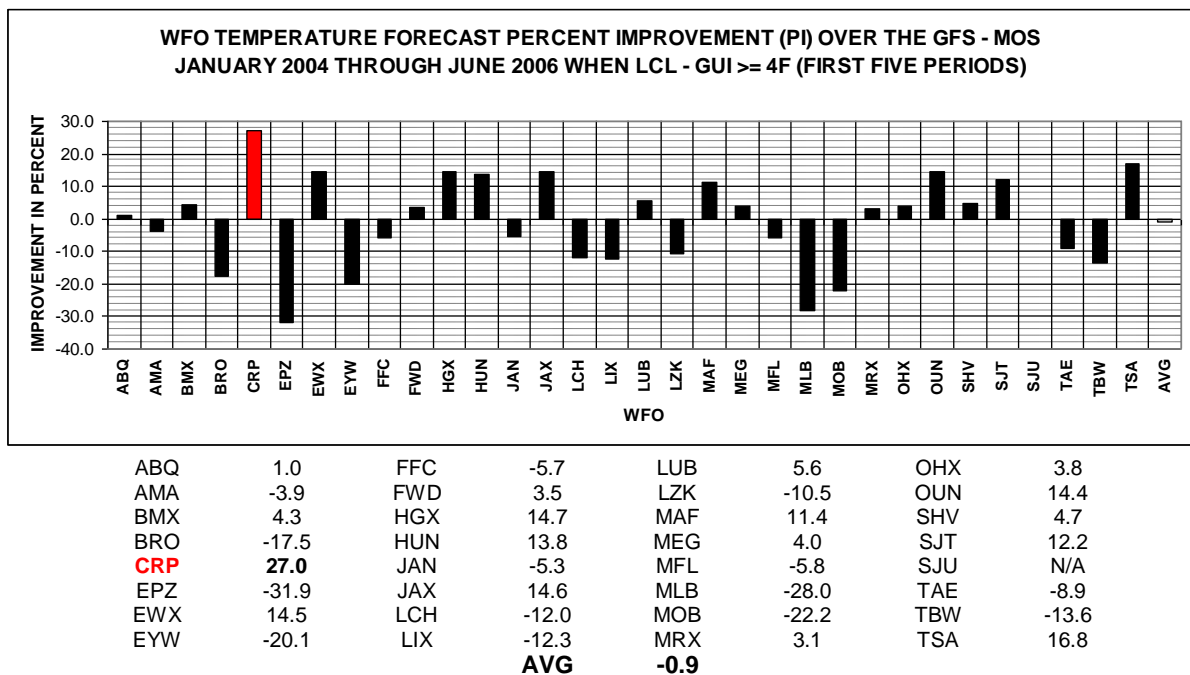


Figure 4: Same as Figure 3, except for cases where the WFO forecast (LCL) differed from the GFS-MOS (GUI) by four or more degrees Fahrenheit (4°F). Note that SJU was not plotted to provide a better graph window for the remaining station results.

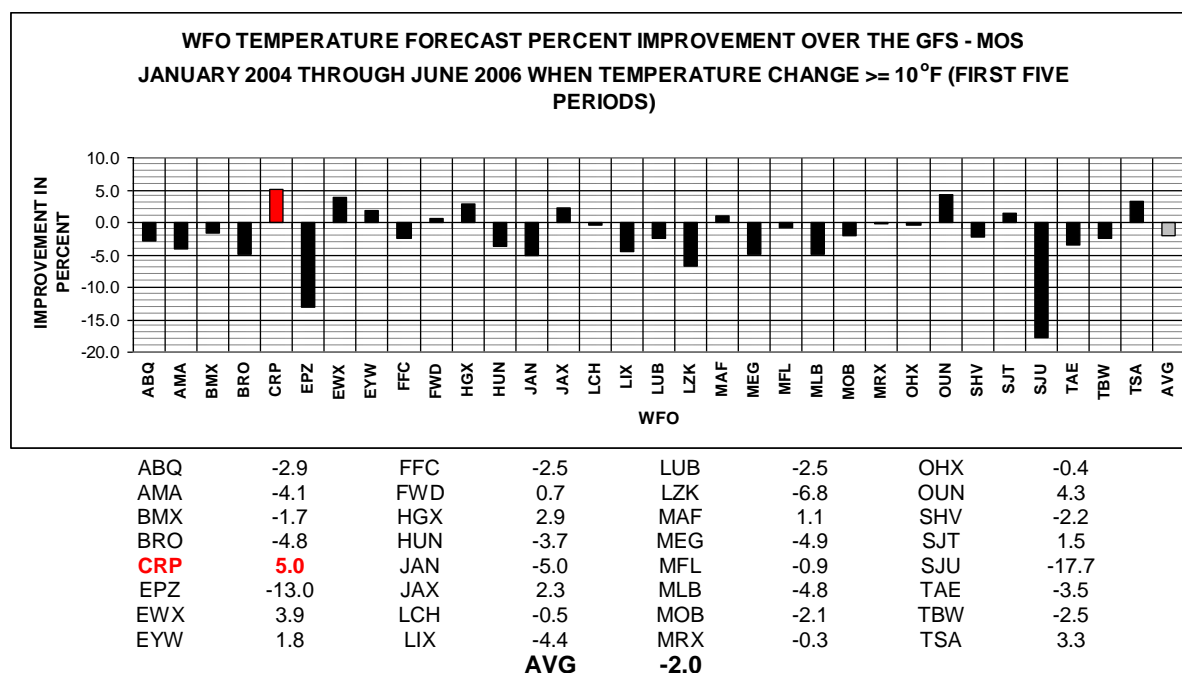


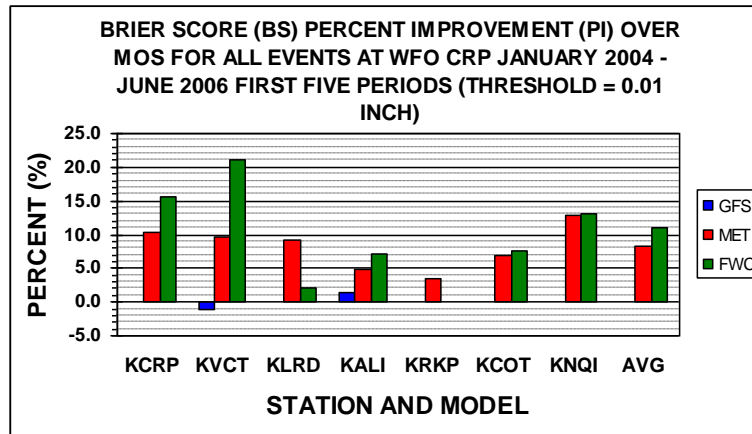
Figure 5: Same as Figure 4, except for cases when the 24 hour observed temperature change was greater than or equal to 10 degrees Fahrenheit (10°F).

V. Precipitation Verification Results

Figure 6 shows the average WFO Corpus Christi Brier Score improvements over each MOS guidance for the seven stations for the first five periods. There was little to no difference in WFO Corpus Christi scores when compared with GFS-MOS scores. However, WFO Corpus Christi scores were better than MET-MOS and FWC-MOS scores at all stations. When the Brier Score precipitation threshold was changed to 0.10 inches or more (Figure 7), WFO Corpus Christi scores showed a slight improvement over GFS-MOS scores at KCRP, KVCT, KALI, KRKP, and KNQI. Interestingly however, the FWC-MOS actually had better scores than WFO Corpus Christi scores, and at most stations were better than GFS-MOS and MET-MOS scores. Similar results of comparisons between WFO Corpus Christi, GFS-MOS, MET-MOS and FWC-MOS scores were found when the Brier Score threshold was increased to 0.25 inches (not shown). These results suggest (at least to some degree) that the FWC-MOS provides better forecasts when heavier precipitation occurred (at least at WFO Corpus Christi).

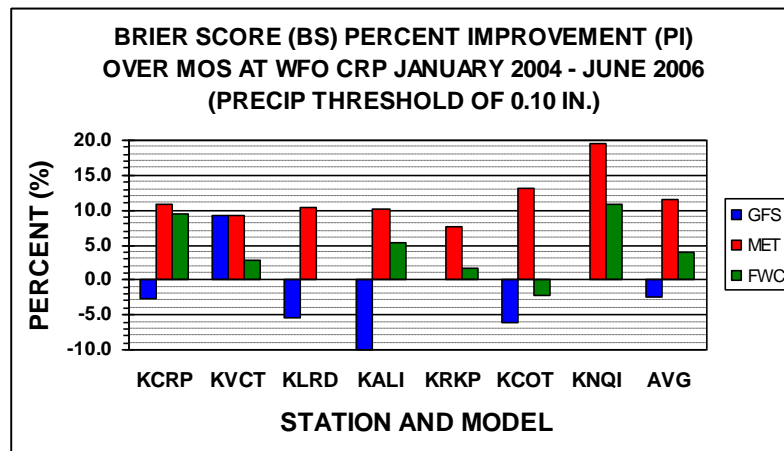
Figure 8 shows the Brier Score percent improvement over the GFS-MOS for all WFOs in SR for the first five periods. WFO Corpus Christi was second in the region for improvement over

the GFS-MOS (SJU was 1st)⁸. Also, there were only seven stations that showed some improvement over the GFS-MOS. It should also be noted that improvements for any WFOs were not substantial. This lack of improvement may be due in part to using a point verification scheme for precipitation, since



Station	GFS	MET	FWC
KCRP	0.0	10.3	15.6
KVCT	-1.1	9.6	21.1
KLRD	0.0	9.3	2.0
KALI	1.3	4.9	7.1
KRKP	0.0	3.5	N/A
KCOT	0.0	6.8	7.6
KNQI	0.0	12.9	13.0
AVG	0.0	8.2	11.1

Figure 6: WFO Corpus Christi average percent improvement of Brier Score over the GFS-MOS, MET-MOS, and FWC-MOS scores for the seven verification sites. Note that while WFO Corpus Christi scores improved MET-MOS and FWC-MOS scores, there was little or no improvement between the WFO Corpus Christi and GFS-MOS scores.

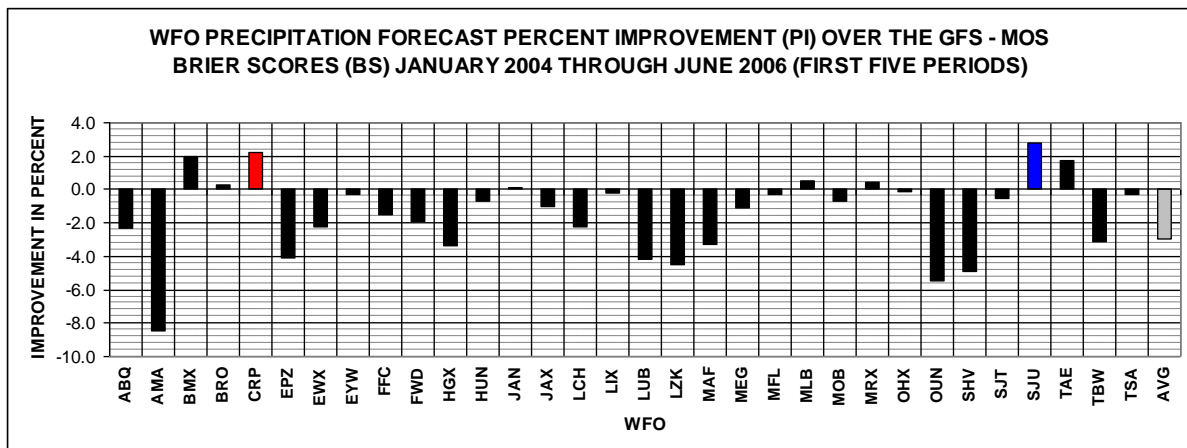


Station	GFS	MET	FWC
KCRP	9.5	10.9	-2.7
KVCT	2.9	9.3	9.2
KLRD	0.0	10.4	-5.4
KALI	5.4	10.2	-9.9
KRKP	1.6	7.6	N/A
KCOT	-2.2	13.2	-6.2

⁸ When all 14 periods were used, WFO Corpus Christi remained in 2nd place in Southern Region behind SJU.

KNQI	10.9	19.6	0.0
AVG	4.0	11.6	-2.5

Figure 7: WFO Corpus Christi percent improvement over MOS Brier Score when the 12 hour precipitation threshold is increased from 0.01 inches to 0.10 inches. While an improvement of CCF scores over GFS-MOS scores was observed, the opposite was true for FWC-MOS scores.



ABQ	-2.3	FFC	-1.5	LUB	-4.2	OHX	-0.1
AMA	-8.5	FWD	-1.9	LZK	-4.5	OUN	-5.5
BMX	2.0	HGX	-3.4	MAF	-3.3	SHV	-4.9
BRO	0.3	HUN	-0.7	MEG	-1.1	SJT	-0.5
CRP	2.2	JAN	0.1	MFL	-0.3	SJU	2.8
EPZ	-4.1	JAX	-1.0	MLB	0.5	TAE	1.7
EWX	-2.2	LCH	-2.2	MOB	-0.7	TBW	-3.1
EYW	-0.3	LIX	-0.2	MRX	0.4	TSA	-0.3
		AVG	-3.0				

Figure 8: Brier Score percent improvement over the GFS-MOS at NWS Southern Region WFOs. WFO CORPUS CHRISTI is in red⁹, with the region average in gray. Stations with improvements greater than WFO Corpus Christi are *italicized bold* in the table.

rainfall can vary significantly over an area. Also, perhaps an interval longer than 30 months would be more representative of an accurate comparison between the GFS-MOS and the associated WFO forecasts.

Table 3 shows the percent improvement over the GFS-MOS for Brier Score at all WFOs nationally for the 30 month period for the first five periods. As can be seen from the table, WFO Corpus Christi ranked 9th nationally (LOX was 1st). However, when all 14 periods are

⁹ Part of the reason for the discrepancy between Corpus Christi's percent improvement in Figure 8 and that in Figure 6 may be because KALI, KRKP and KCOT were added to the CCF in April 2004 and not in January 2004.

considered, WFO Corpus Christi was 4th in the nation (Table 4). Unfortunately, most offices showed no improvement over the GFS-MOS. Again, this may in part be due to the fact that verification statistics are performed on a point basis rather than by areal coverage.

Figure 9 illustrates BS improvements in SR when WFO PoPs (LCL) and GFS-MOS POPs (GUI) differ by 20 percent or more. From this test, only three WFOs in the region improved on GFS-MOS forecasts: San Juan, Corpus Christi and Key West. Also, of the three stations that showed improvement over the GFS-MOS, only WFO San Juan increased its improvement in this special case (compare Figure 8 with Figure 9). Comparing these two figures also show that only WFO Key West improved GFS-MOS forecasts when the LCL PoP and GFS-MOS PoP differed by 20% or more (Figure 9), after losing to the GFS-MOS for all GFS-WFO comparisons (Figure 8).

WFO BRIER SCORE (BS) PERCENT IMPROVEMENT (percent improvement) OVER THE GFS MOS JANUARY 2004 THROUGH JUNE 2006 (FIRST FIVE PERIODS)

WFO	%	WFO	%	WFO	&	WFO	%	WFO	&	WFO	%	WFO	%
ABQ	-2.3	BTV	-2.3	EPZ	-4.1	HFO	-10.3	LOT	-2.6	MTR	-2.5	RLX	-0.1
ABR	-9.3	BUF	-5.2	EWX	-2.2	HGX	-3.4	LOX	7.5	OAX	-4.7	RNK	-0.2
AFC	-6.6	BYZ	-11.4	EYW	-0.3	HNX	-10.3	LSX	-2.3	OHX	-0.1	SEW	-1.8
AFG	-7.7	CAE	0.5	FFC	-1.5	HUN	-0.7	LUB	-4.2	OKX	-0.1	SGF	-1.5
AJK	-8.7	CAR	-7.3	FGF	-10.4	ICT	-0.1	LWX	-1.4	OTX	3.7	SGX	2.7
AKQ	-4.0	CHS	-3.9	FGZ	3.0	ILM	-0.7	LZK	-4.5	OUN	-5.5	SHV	-4.9
ALY	-0.8	CLE	-3.6	FSD	-4.0	ILN	-1.1	MAF	-3.3	PAH	-2.5	SJT	-0.5
AMA	-8.5	CRP	2.2	FWA	N/A	ILX	-5.8	MEG	-1.1	PBZ	-5.7	SJU	2.8
APX	-9.8	CTP	-2.6	FWD	-1.9	IND	-1.3	MFR	-0.3	PDT	2.2	SLC	6.1
ARX	-5.2	CYS	-6.5	GGW	-6.5	IWX	-6.2	MFL	-0.3	PGU	N/A	STO	5.3
BGM	-5.5	DDC	-1.3	GID	-5.5	JAN	0.1	MHX	-3.6	PHI	-2.5	TAE	1.3
										percent improvementH			
BIS	-9.0	DLH	-12.7	GJT	-0.3	JAX	-1.0	MKX	0.6		-3.6	TBW	-3.1
BMX	2.0	DMX	0.2	GLD	-1.2	JKL	0.8	MLB	0.5	PQR	-7.7	TFX	-0.7
BOI	1.1	DTX	-5.0	GRB	-2.6	LBF	-7.5	MOB	-0.7	PSR	4.2	TOP	-3.2
BOU	-4.0	DVN	-1.9	GRR	-10.1	LCH	-2.2	MPX	-6.2	PUB	-0.7	TSA	-0.3
BOX	-0.6	EAX	-1.8	GSP	-1.1	LIX	-0.2	MQT	-26.3	RAH	-0.8	TWC	1.4
BRO	0.3	EKA	-5.5	GYX	-5.4	LKN	-0.5	MRX	0.4	REV	-0.7	UNR	-6.5
						LMK	-2.9	MSO	-4.4	RIW	-4.7	VEF	-3.0

Table 3: percent improvement over GFS-MOS BS at all NWS WFOs for the first five periods. WFO Corpus Christi is in bold. Stations with improvements greater than WFO Corpus Christi are *italicized bold* in the table. WFO Corpus Christi was ninth in the nation for improvement over the GFS-MOS.

WFO BRIER SCORE PERCENT IMPROVEMENT OVER THE GFS MOS JANUARY 2004 THROUGH JUNE 2006 (ALL 14 PERIODS)

WFO	%	WFO	%	WFO	&	WFO	%	WFO	&	WFO	%	WFO	%
ABQ	-3.4	BTV	-3.5	EPZ	-4.3	HFO	-9.7	LOT	-2.6	MTR	-6.1	RLX	-2.3
ABR	-6.0	BUF	-3.9	EWX	-2.2	HGX	-2.7	LOX	-1.0	OAX	-1.6	RNK	-1.6
AFC	-15.1	BYZ	-8.7	EYW	-1.8	HNX	-8.5	LSX	-2.3	OHX	-4.0	SEW	-5.6
AFG	-14.7	CAE	-1.1	FFC	-11.7	HUN	-3.2	LUB	-2.9	OKX	-0.6	SGF	-2.4
AJK	-7.8	CAR	-4.6	FGF	0.5	ICT	-1.5	LWX	-1.6	OTX	1.2	SGX	-0.9
AKQ	-3.2	CHS	-2.9	FGZ	-2.6	ILM	-1.5	LZK	-3.5	OUN	-2.7	SHV	-5.9
ALY	-1.8	CLE	-4.5	FSD	N/A	ILN	-3.7	MAF	-3.0	PAH	-3.6	SJT	-1.0
AMA	-6.5	CRP	1.9	FWA	-5.0	ILX	-3.5	MEG	-2.7	PBZ	-5.2	SJU	4.1

APX	-6.6	CTP	-3.1	FWD	-8.2	IND	-4.1	MFR	-2.0	PDT	0.2	SLC	3.5
ARX	-2.9	CYS	-5.1	GGW	-3.9	IWX	-6.1	MFL	-2.8	PGU	N/A	STO	-3.2
BGM	-5.5	DDC	-4.5	GID	-1.5	JAN	-0.8	MHX	-3.7	PHI	-2.1	TAE	-0.9
										percent			
BIS	-5.6	DLH	-9.1	GJT	-3.2	JAX	-2.6	MKX	-1.8	improvementH	-3.8	TBW	-3.5
BMX	1.2	DMX	0.0	GLD	-1.6	JKL	-2.2	MLB	-1.6	PQR	-11.5	TFX	-4.1
BOI	-0.1	DTX	-3.6	GRB	-4.9	LBF	0.7	MOB	-1.3	PSR	2.5	TOP	-2.8
BOU	-4.9	DVN	-0.4	GRR	-1.5	LCH	-4.7	MPX	-4.0	PUB	-1.1	TSA	-1.1
BOX	0.7	EAX	-1.3	GSP	-3.7	LIX	-2.6	MQT	-15.3	RAH	-0.5	TWC	-0.7
BRO	-0.3	EKA	-8.9	GYX	-4.3	LKN	-1.3	MRX	-2.2	REV	-1.1	UNR	-6.8
						LMK	-0.5	MSO	-3.2	RIW	-4.5	VEF	-1.3

Table 4: Same as Table 3, except for all 14 periods. Note that WFO Corpus Christi was now ranked 4th nationally for improvement over the GFS-MOS.

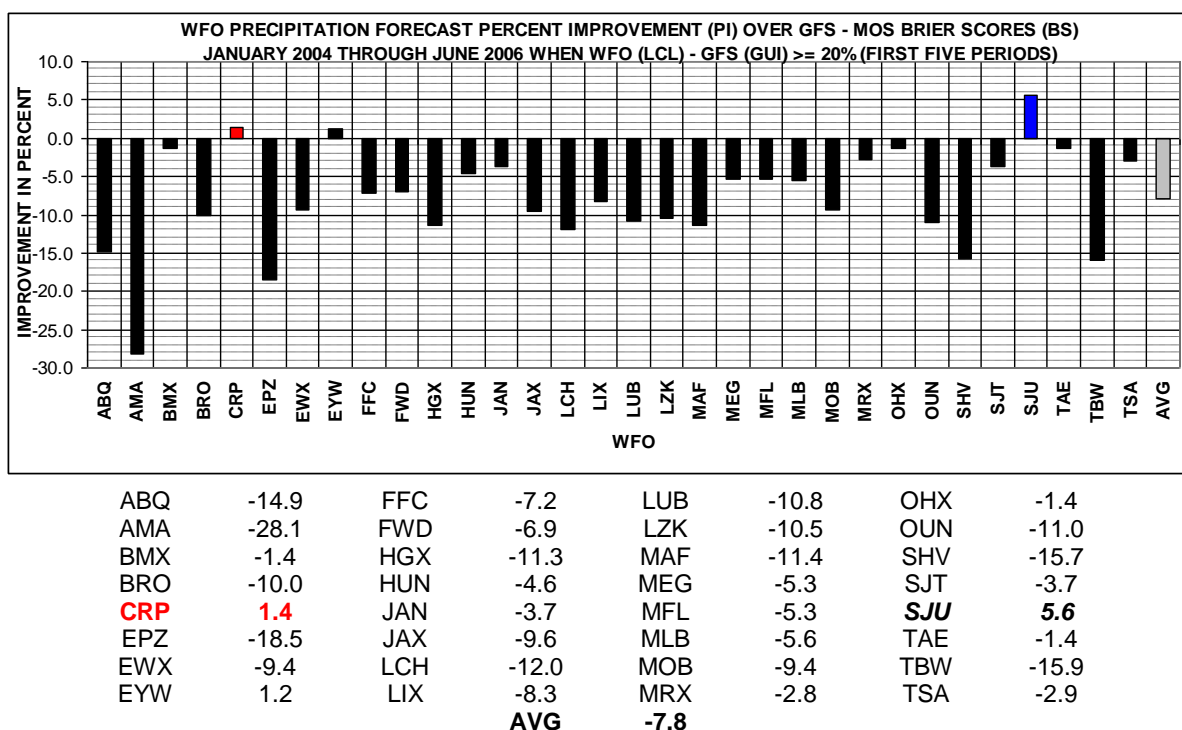


Figure 9: Same as Figure 8, except for cases when the WFO POP (LCL) differs from the GFS-MOS POP (GUI) by 20% or more.

Part of the explanation for these unimpressive precipitation results in SR may have resulted when a WFO forecasts a POP of ‘0’ when a measurable rainfall event occurred. Figure 10 shows the percentage of time the WFO POP (LCL) or the GFS-MOS POP (GUI) was zero in the first five periods, yet measurable precipitation occurred during that 12 hour period. As these results show, WFO percentages were higher than GFS-MOS percentages at most offices. In fact, only seven WFOs had lower percentages than the GFS-MOS. This is important, since the BS method assigns a “1” (i.e., the worst possible score) for missed events (see Equation 3). Because of this, the BS can become easily inflated by missed events. Thus, most forecast offices would likely benefit by refraining from using a zero POP when rainfall is unlikely, but still conceivable (i.e., trying to “beat MOS” when the MOS POP is very low, e.g. less than 10

percent). Finally, it should be mentioned that some “events” may not really be missed, but could result from “false tips” from automated observation stations. As is widely known, many times ASOS (Automation of Surface Observation System) sites may report measurable precipitation in their observations when no rainfall occurs. These occurrences, known as “false tips”, could result from many factors, including condensation from dense fog, from insects or animals, or other unknown phenomenon. Although some precipitation quality control exists at the national verification site (see the following link: <https://verification.nws.noaa.gov/verification/public/policy/POP-QC.pdf>), there may be some instances when these “false tips” may not be identified by the quality control procedures. Each false tip not removed by quality control will skew the BS numbers higher.

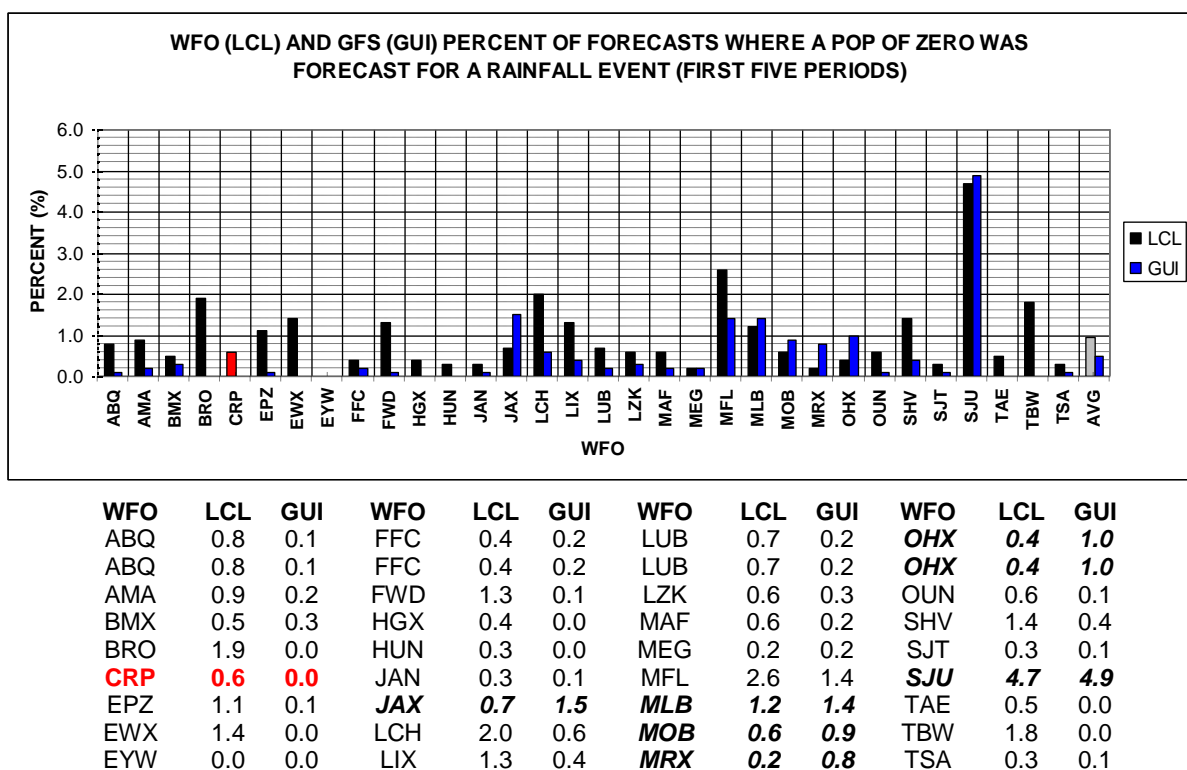


Figure 10: Percentage of events where either the WFO (LCL) or GFS (GUI) forecast a POP of zero and rainfall was measured during the 12-hour period. Stations that had a lower percentage than the GFS are shown in bold italics in the accompanying table.

VI. Possible Reasons for WFO Corpus Christi Improvements Over the GFS-MOS Forecasts

As seen from the previous sections, WFO Corpus Christi was able to provide the greatest improvements over the GFS-MOS in temperature forecasts not just in SR, but nationally as well. Also, WFO Corpus Christi was second in SR in improving the GFS-MOS POP guidance, and was in the top 10 nationally. Some of the *possible reasons* for the success at

WFO Corpus Christi are listed below. The reasons outlined are the author's opinions (and other forecasters at WFO Corpus Christi), and are not meant to be taken as an indictment on any forecast office who adheres to any policies or ideas different from those listed below. Since the upcoming reasons are opinions (and not facts), one cannot say with certainty that any or all of these points are the direct result for the verification success seen at WFO Corpus Christi. Rather, these can be viewed as a “best practices” guide used at WFO Corpus Christi in the goal of providing the best possible forecasts to our customers.

A. Short-Term/Long-Term Forecaster Concept

Assuming that most WFOs have two forecasters on shift continuously, office forecast responsibilities can be segmented in many ways. Some approaches may include: public vs. aviation/marine duties, synoptic vs. mesoscale duties, public vs. fire weather duties, etc. When formulating forecasts for its area of responsibility, WFO Corpus Christi separates grid responsibilities by short and long term forecasts. When new forecast packages are issued for the 4 AM local time (0000 UTC model runs) and 4 PM local time (1200 UTC model runs), in most situations the short-term forecaster will create grids (and generate forecast products) for the first three periods. The short-term forecaster also is responsible for other products, such as aviation forecasts (TAFs), short-term forecasts (NOWs)¹⁰, advisories, warnings, and public forecast updates (when needed). The long-term forecaster provides grids and forecasts for the remaining periods, and can assist the short-term forecaster if necessary. When the short-term forecaster's workload is increased due to critical or significant weather (i.e., active weather such as thunderstorms, weather affecting TAFs, ongoing watches or warnings, etc.), or when the formulation of a forecast requires more time or coordination among offices, the long-term forecaster will inherit more periods as part of his or her forecast responsibilities. During extremely active weather, the short-term forecaster may do as little as one period, or in extreme cases, the long-term person will do the entire forecast. Since the long-term forecaster has a greater grid workload, s/he starts the shift an hour earlier than the short term forecaster, allowing more time to formulate the forecast.

One advantage of this concept is that it allows the short-term forecaster additional time to compose the earliest forecast periods in the package, in order to provide the public with the best possible products and services, especially during high impact events. Another advantage is that the short-term forecaster has additional time to add detail to the forecast weather elements when needed (e.g. fine tune temperature forecasts for specific locations, or increase/decrease wind speeds over certain portions of the area where local effects are known). Also, since WFO Corpus Christi forecasters generally work five or six consecutive short or long-term shifts, they (especially the long-term person) can often observe trends or changes in model forecasts with time, noting model inconsistencies or notable changes in forecast sensible weather elements. Finally, the transition of responsibility between the short-term forecaster's periods of responsibility and those of the long-term forecaster requires coordination between the two, ensuring that the forecast grids do not have discontinuities between the final grids from the short-term forecaster to the initial grids of the long-term forecaster. The short-term/long-term forecaster concept has been used for several years at WFO Corpus Christi, has worked well, and is preferred by the operational staff. This approach has been more effective

¹⁰ During non-severe weather events, the Hydrometeorological Technician (HMT) or Intern will often issue NOWs.

than segmenting forecaster responsibilities by the public versus aviation/marine duties (which initially was the WFO Corpus Christi approach when forecast grids were introduced), or by having only one person responsible for the entire forecast and the other forecaster having mesoscale responsibilities (which in tranquil weather situations creates an uneven workload).

B. Using All Available Model Data and Grids in the Creation of a WFO Forecast

WFO Corpus Christi operates on the philosophy of using all available model data (including available model grids) when formulating a forecast. This includes the use of the Internet for models not available in AWIPS (e.g. the Canadian model). WFO Corpus Christi utilizes this approach for the following reasons. First, some models may perform better than others during certain weather scenarios or events, may show more consistency from model run to model run, or may provide better weather elements than another model. Additionally, by using several models, forecasters can look for model consensus, observing which models agree with a certain scenario and which models are the outliers. In these instances, it would make sense to use the model (or models) that the forecaster has the most confidence in. This maintains the forecaster as an important element in the NWS forecast process.

Second, there can be instances when a “favored” model deviates from a particular scenario (i.e., “flip-flopped”) from run to run in the long-term portion of the forecast (day three or later). This situation has been observed by Corpus Christi forecasters from time to time. Obviously, this would cause problems not only with Inter-Site-Coordination (ISC), but with the public/customer perception of the NWS forecast. For example, one model (e.g. the GFS) may bring a significant cold front through South Texas on one model run, and then stall the boundary north of the area on the next model run. In this scenario, radical changes in forecast temperatures, winds, humidity, precipitation, and other meteorological fields would occur if that model was exclusively used for the WFO forecast. If frequent changes to the model solution repeatedly occur, and forecasters blindly introduce them to the public forecast package with each run, public reaction could turn negative at our perceived indecisiveness. A philosophy sometimes used by some operational forecasters in this model inconsistency situation is to maintain the basic essence of the previous forecast, or slightly modify the previous forecast by trending toward the newer solution. Often times, the model will eventually revert back to near its original scenario (sometimes even on the next model run). Therefore, observing model trends may avoid unnecessary and drastic forecast changes. However, should a model (or models) show a consistency toward the new solution (e.g. from ensemble forecasts), then the forecasters will adjust their forecasts accordingly.

Third, a single model does not always provide the best forecast from all available models. Certain models may have biases with the timing, strength, and location of certain meteorological phenomenon (for additional information, see the following links: <http://www.emc.ncep.noaa.gov/modelinfo/index.html>, and <http://www.emc.ncep.noaa.gov/modelperf/>). In one situation, one model may provide a preferred solution while another scenario may be handled more appropriately by a different model. A forecaster needs to have the discretion to use the “model of choice” (if any) in the forecast process. Also, at times a blend of model solutions in the WFO forecast would be advantageous. In other words, some parameters of a model solution may be preferred, while another model may provide a better solution in other forecast elements. In this case, the

forecaster can use the best aspects of each available model, providing its customers with the best possible forecast products. Although downloading one particular model (and adding detail to it) may be more time efficient for coordinating (and align their forecast elements) with surrounding offices, it seems more appropriate to use the preferred model solution (if any) for a particular forecast element, or to simply modify the previous forecast. Better public service is provided when the forecaster has the ability to utilize all available model data to formulate the NWS forecast.

C. Attention to Detail in Forecast Grids

Awareness of the subtleties and characteristics of certain areas within the Corpus Christi forecast area of responsibility (either from experience or from more experienced forecasters) is of paramount importance. Forecasters at WFO Corpus Christi are strongly encouraged to modify forecast grids to account for these subtleties. The Coastal Bend region of South Texas provides many challenges to the forecaster. The area can either be in a continental environment, tropical environment, or a combination of the two. Also, the area of responsibility is surrounded by data sparse regions, including the mountains of Mexico as well as the Gulf of Mexico, which at times can impact model forecast solutions (especially when Mexican upper air data is unavailable). Variations and gradients in sensible weather elements can result due to the proximity to the Gulf of Mexico, the bend in the coastline, the environmental wind profile, and other factors. Forecasters at WFO Corpus Christi take into account these variations by adding detail to their grids. This can be accomplished either manually (e.g. by using the pencil tool in the Graphical Forecast Editor, or GFE), or by the use of several “Smart Tools” within the Interactive Forecast Preparation System (IFPS). IFPS Smart Tools allow forecasters to fine tune/modify any of the gridded data easily. These tools also help to shorten the time needed to add detail to forecasts in locations where synoptic scale models have insufficient special resolution to accurately predict certain weather elements.

D. Monthly and Six Month Office Verification Statistics

Rather than waiting for the compilation of temperature and precipitation verification statistics from the national verification web site, observed and forecast (WFO and model) temperature and precipitation data is collected every 12 hours. Quality control of observed values also is performed. Every month, WFO Corpus Christi temperature and precipitation verification statistics are computed for each verification site, and presented to the staff in either graphical or tabular form. Every six months, verification statistics are computed for the cool season (October through March) and warm season (April through September) for each verification station.

The monthly and six month verification statistics include various CCF and MOS comparisons. For temperatures, CCF and MOS absolute errors and biases (warm or cool) are provided for each period, along with other pertinent statistics. Precipitation statistics include CCF and MOS BS and POP comparisons for measurable rain vs. non measurable rain events. For further details concerning the Corpus Christi verification program and what statistics are provided, see Wilk (2005). These monthly and seasonal verification summaries help the forecasters identify possible shortcomings in each MOS method, and keep them abreast on how WFO Corpus Christi forecasts compare with each MOS method at each verification site.

E. Individual Verification Statistics Provided To Each Forecaster Every Six Months

Every six months (shortly after the end of the cool and warm seasons), individual temperature and precipitation verification statistics are given to each forecaster for the previous six months. Since the number of periods for which the short and long-term forecaster is responsible for can vary per shift, the number of periods each forecaster is responsible for is archived by placing this information in a one line text file created on the early morning and the afternoon shifts (for the 0000 UTC and 1200 UTC model runs, respectively). This file provides the date, forecast cycle, short-term forecaster number, long-term forecaster number, and the number of periods that the short-term forecaster provided. These files are then used in another program, which separates the data by forecaster number and computes his or her verification statistics for the six month period. Each forecaster receives his or her results, and can see how well s/he performed compared to MOS temperature errors, temperature biases, POP forecasts and BS for each verification site. For more information concerning individual forecaster results, see Wilk (2005). Thus, the forecasters can use this information to hopefully improve their forecasts at any or all stations, and therefore improve WFO Corpus Christi verification results.

F. Station Forecaster Contest

After each warm and cool season, each forecaster's results are compared with MOS and with his or her fellow forecasters. A forecaster is credited (penalized) for having a better (worse) forecast than the consensus MOS forecast (i.e., the average between each MOS method). The forecasters with the lowest adjusted errors for temperatures and the lowest adjusted BS for precipitation are given an award for their performance during that six month period (see Wilk, 2005). It should be noted that only the forecasters who performed well are acknowledged (i.e., information concerning forecasters who did poorly during the six month interval is not divulged). The goal of these contests is to provide an atmosphere of friendly competition among forecasters, in hopes to improve individual forecaster results and station verification statistics. These contests also provide an additional incentive to try and formulate the best possible temperature and precipitation forecasts, in hopes of giving that forecaster "bragging rights" should he or she win the temperature or precipitation contest for that six month period.

G. Use of GFE/ISC Tools

Forecasters at WFO Corpus Christi are strongly encouraged to use the tools available in the Graphical Forecast Editor/Interactive Forecast Preparation System (GFE/IFPS). Inter-Site Coordination (ISC) among neighboring WFOs is also strongly encouraged. ISC can be accomplished in several ways, but for this paper, only two will be discussed. First, the short and long-term forecasters log onto the 12Planet collaboration tool on AWIPS as part of their forecaster duties (AWIPS web address is: <http://165.92.25.180:8080/servlet/onetoplanet.web.runtime.infolet.InfoServlet>). On 12Planet, forecasters can chat with neighboring WFOs regarding any aspects of the upcoming forecast, whether it is the timing of a front, probability of precipitation, or other sensible weather elements. This allows forecasters to share ideas and coordinate with other offices in hopes to provide the best possible forecasts to our customers, as well as to avoid large differences in any weather elements along WFO boundaries.

Forecasters are also encouraged to use the ISC Mode in the GFE to compare the WFO Corpus Christi forecast with surrounding offices. Through the use of ISC mode in the GFE, forecasters can see what other offices are predicting for each weather grid. If discrepancies between two or more offices exist, the forecaster may either reconsider his or her values for that forecast element (and modify them to be more in line with the adjoining office) or, if they feel sufficiently confident about their forecast, coordinate/collaborate with that office via 12Planet, telephone, the Area Forecast Discussion (AFD), or other methods. In other words, forecasters at WFO Corpus Christi also use ISC to view temperature and precipitation forecasts from surrounding offices to either confirm their forecast values, adjust their forecasts accordingly, or to further coordinate with the office(s) when discrepancies arise. Thus, ISC can sometimes be used as a “second opinion” pertaining to forecast elements in question. However, there are times when temperature and precipitation discrepancies between WFO Corpus Christi and a neighboring office remain despite attempts to resolve these differences. If the forecaster feels strongly enough, it is the policy of WFO Corpus Christi to allow these discrepancies to exist despite the unsuccessful attempts to resolve them.

VII. Summary

Comparisons between CCF and MOS temperature forecasts from 1 January 2004 through 30 June 2006 for the first five periods indicated that CCF errors were nearly 11.5% lower than GFS-MOS forecasts, 15% lower than MET-MOS forecasts, and about 22% lower than FWC-MOS forecasts. The greatest improvements over the GFS-MOS occurred over the inland verification sites west of KCorpus Christi, namely at KLRD, KALI, and KCOT. CCF improvements over MOS were found to be greater for maximum temperatures than for minimum temperatures. When compared with other WFOs in SR and over the entire NWS, WFO Corpus Christi ranked first in improving GFS-MOS forecasts for the first five periods as well as for all 14 periods. WFO Corpus Christi also was best in the region for improving GFS-MOS forecasts for the first five periods when the WFO temperature forecast differed from the GFS-MOS forecast by 4°F or greater, and when the 24 hour observed temperature change was 10°F or larger.

When comparing CCF precipitation forecasts with MOS forecasts, CCF BS were about the same as GFS-MOS scores, but overall were lower (better) than MET-MOS scores and FWC-MOS scores. When the BS threshold was increased to 0.10 inches or more, CCF scores were slightly better than GFS-MOS scores; however, FWC-MOS scores were better than CCF scores (as well as GFS-MOS and MET-MOS scores). This suggests that the FWC-MOS may provide better results for more significant rainfall events, but are usually worse for light rainfall events. When compared with other WFOs in SR and over the entire NWS, WFO Corpus Christi was second best in improving GFS-MOS forecasts for the first five periods (as well as for all fourteen periods) in the region, and was in the top ten nationally. WFO Corpus Christi also was second in SR for improving GFS-MOS forecasts for the first five periods when the WFO POPs forecasts differed from GFS-MOS forecasts by 20% or more.

Part of the reason for WFO Corpus Christi’s verification success may result from certain forecast and station procedures used operationally. Dividing forecast operations into short and long-term duties allows the short-term forecaster additional time to work on fewer grids,

providing the opportunity for greater forecast detail (and hopefully more accuracy) in the first few periods, especially for high impact events. Also, WFO Corpus Christi encourages the use of any and all models in the formulation of its forecasts, not solely relying on one model as a starting point in the forecast process. Corpus Christi forecasters also are encouraged to use ISC and GFE Smart Tools in their forecasts. Finally, WFO Corpus Christi has a robust verification program, providing timely monthly and seasonal temperature and precipitation verification statistics, individual forecaster statistics, as well as temperature and precipitation forecast contests. These procedures are employed at WFO Corpus Christi to help improve verification statistics, therefore providing better temperature and precipitation forecasts to our customers.

VIII. Acknowledgements

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